Hybrid Settlers - Integrating Dynamic Tiles into a Physical Board Game Using Electrochromic Displays

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Figure 1: Hybrid Settlers. Settlers of Catan with four dynamic tiles.

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Abstract

In this paper we present a novel method of hybridizing physical board games by adding dynamic and digitally controlled fields utilizing electrochromic inks. In particular we built electrochromic displays that fit the hexagon fields on the Settlers of Catan board game and thereby added the ability to change a fields resources during game play. In this paper we report on the prototypical implementation and two preliminary studies that indicate how these dynamic fields can increase the excitement and reward of playing the game.

Author Keywords

boardgames, settlers of catan, electrochromic displays

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** User studies;

Introduction

While digital games are increasing in popularity and market share, physical board games still enjoy great popularity due to the tangible elements and social aspects [8, 11]. In recent years the hybridization of board games - introducing digital aspects into the physical gameplay - has been investigated [7]. Not only have mixed reality approaches [3, 2] explored, but even products such as Hasbro's zAPPed

range of boardgames been released to the market[1]. These games integrated the users mobile device into the game play, but have however, been discontinued as of now. This might be due to the need of an expensive additional device.

In a 2004 study, manufacturers, players and game authors were interviewed and asked about potential board game extensions. The results identified a digitally controlled changing gameboard composition as one of the most sought after electronic enhancement [1]. While physical bricks could enable this, they would require some remodelling which might disturb the game flow. A complete digital gameboard (e.g. an OLED display or a projection) would allow for full flexibility but also would remove some of the appreciated aspects of board games as we all as require complex control mechanisms.

In this work we propose the usage of electrochromic ink as a low-cost and low-energy alternative to create dynamic gameboards. In recent years it has become possible to fabricate transparent and non-uniform displays using electrochromic ink [5] and they have been used for a variety of different application ranging from simple paper augmentation as in game cards [5] to complex wearables [5, 4]. This display technology allows creating tangible and dynamic elements for board games that can be created in different forms and have relatively small requirements in terms of needed control circuits and energy supply.

To demonstrate the viability of this technology in board games we present Hybrid Settlers, an augmented version of Settlers of Catan in this paper. It features dynamic tiles which randomly change board game tiles during gameplay or manually by using a Bluetooth enabled controller. We present the prototypical implementation as well as an initial evaluation that explores whether adding dynamic tiles increase entertainment value and/or excitement. Our findings suggest that there is a benefit in adding dynamic tiles to increase excitement and reward.

[1] https://newsroom.hasbro.com/index.php/news-releases/news-release-details/game-life-monopoly-and-battleship-get-zapped-new-revolutionary

Related Work

While there has been extensive evaluation of user experience in digital games, comparably little work has focused its attention on board games or hybrid board games in HCI. In this work we particularly focus on eurostyle board games that tend to favour player interaction and strategic thinking over luck. The differentiation factors that are particular about these games such as social interaction and materiality of the boardgame have been well documented and highlighted by Woods [11]. Rogerson et al. similarly found, in their investigation into the enthusiasts' culture of boardgamers, that the material aspect of the game even down to the box of the game, as well as the environmental setting are important aspect of the overall experience [8]. These works suggest that when adding digital elements not to interfere with the materiality and social aspects of the board game.

Several different approaches to hybridizing board games have been investigated, especially using Augmented- and Mixed Reality. For example, Huynh et al. combined smartphones with physical game pieces to create an AR tabletop boardgame, where several players have to cooperate to achieve the goals [3]. Echtler explored the possibility of live streaming gameboards and projection based AR to allow hybrid board games with remote players [2]. However, these approaches require extra devices that would create different experiences for different users or heavy instrumentation of the environment. Both approaches might be less favourable in a commercial

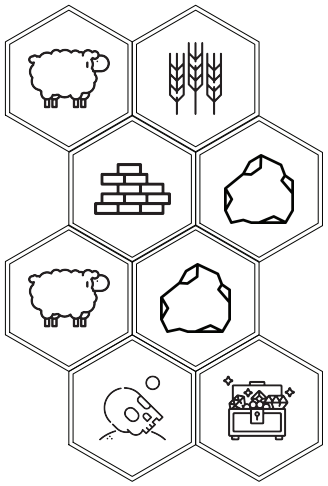

Figure 2: Dynamic tile designs. *Row 1*: wool and grain, *Row 2*: brick and ore, *Row 3*: wool and ore, *Row 4*: desert and golden chest

Figure 3: Fabricated dynamic tile with brick and ore resource. Ore is visible and thereby active.

setting.

Very recently Kankainen and Paavilainen presented 17 guidelines for hybrid board games that they derived from an iterative workshop process with experts [6]. As discussed later we follow (when applicable) their suggestions in our design. Another aspect has been uncovered by Wallace et al. [10]. They found in their investigation of level of automation which more accurately mimics physical board games, that reducing the automation of their digital tabletop game resulted in higher understanding of the state of the game. We decided therefore to limit the autonomy of the digital aspect of our hybridized board game to not take too many deviations from the original game.

Hybrid Settlers

Settlers of Catan

We chose Settlers of Catan for hybridization as it is a highly acclaimed multiplayer and best selling board game [11]. The players settle on the uninhabited island of Catan and has to build settlements, cities and roads by tapping into the natural resources. Two six-sided dice control the resource production and building principalities gain the player's victory points. The original board game consists of 19 hexagonal tiles that each have six natural resources. Each tile has a number between two and twelve assigned to it that the player must toss with the dices to earn the respective resource. The only exception is the desert tile which does not give any resource. Winning the game requires accumulating the required victory points.

One token in the game functions as a robber token, where if 7 is rolled by a player, the token must be moved. It is initially placed on the desert tile (located in the center) and when moved the resources of the tile it is moved to are no longer produced while the token is on the tile. The token also allows the player to steal resource cards from other player's settlements or cities adjacent to the where the robber token is placed. If any player has more than 8 resource cards when a 7 is rolled they must discard half of their resource cards.

Dynamic Tile Design

Electrochromism is the ability of some materials to change their optical properties through chemical oxidation or reduction when an electric current is applied to them. Usually the change is from a color, e.g. blue to a transparent state. The displays do not emit any light, which makes their impression more like changed print. We follow the process described in [5] and used the Ynvisible Ink-Kit[2] to produce the displays. Due to the limitations of electrochromic inks the designs for the dynamic tiles are iconography's of resources. Four icons were designed to represent the following resources: wool, grain, brick and ore (see Fig. 2, row 1-3). These dynamic tiles will function as regular resource tiles that can dynamically change the resource during game play. To add an extra dimension to the game, the desert tile was also made dynamic but instead of only being a desert a possibility of bonus was added to the tile in the form of a golden chest (see Fig. 2, row 4). The golden chest allows the players to select which resource the tile to produces.

The aim behind this design is to add another semi-strategical element towards the game. While inherently Catan is a game that requires strong collaboration between the players, in terms of trading resources etc. we hope that the introduction of these dynamic tiles will not only be used for the players own good but also to maybe harm others and create some artificial competition [9]. The design of these tiles is also in

[2] https://www.ynvisible.com/ec-kit

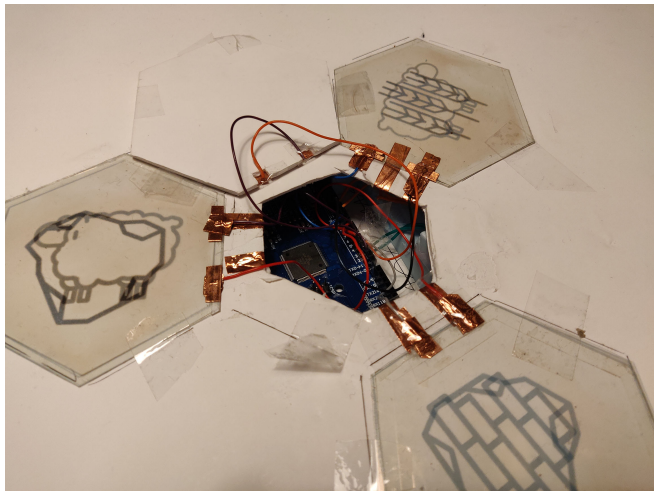

Figure 4: Three dynamic resource tiles connected to the electronics in the hole. Center tile is flipped over to expose and show electronics.

alignment with the guidelines by Kankainen and Paavilainen [6]. They are designed to add extra value, in case of a technical failure it is easy to recover from and the used technology is self contained and should be long-lasting. Furthermore, the general design as well as the rules are meant to be easily customizable. The tiles also keep the tangibility of the original and are completely integrated.

Implementation

A hexagonal shaped hollow box made of foam board was built to place the board game on and hide the electronics that drive the dynamic tiles. The roof of the box had a hole where the center tile of the gameboard is located which allowed wires to the dynamic tiles to be hidden (see Fig. 4).

Four electrochromic displays were fabricated with the same size and hexagonal shape as the original Settlers of Catan tiles (see Fig. 3). Each display requires two general purpose input/output (GPIO) pulse width modulation (PWM) pins and therefore an Arduino Mega was used power the displays. Pulse width modulation was needed to enable powering the displays with different voltages. The Arduino was coded to randomly change the dynamic tiles. Every 30 seconds the algorithm would run a random check which had a 50% chance of changing the tile, if a tile was changed it would stay in it's state for 45s to 180s. After the first preliminary experiment a physical Bluetooth enabled controller with three buttons was developed that allowed the players to manually switch the dynamic resource tiles once per round.

Preliminary studies

To investigate how the hybridization of Settlers of Catan changes game strategies and enjoyment of the game, we conducted two preliminary studies. In the first one the tile would change randomly and in the second one we would give the participants the possibility to change the tiles manually.

Participants

As participants we recruited members of a local board games group to participate in our preliminary studies. Our requirement was that they had extensive experience playing Settlers of Catan. For both iterations of the game we had the same three players (two male, one female), aged 23-27, play the game.

Procedure

We conducted both studies in a living room setting with two observers taking notes. One moderator briefed the participants on the study. To reduce game time players won the game when eight points had been obtained as opposed

Figure 5: Game board during play through of Hybrid Settlers in the study.

to the standard ten points. In the first study we asked the participants to first play a game of regular Settlers of Catan followed by a game of Hybrid Settlers in which the tiles would change randomly as described above. In the second study we again asked participants to play two games, for the first play through the participants could change the resource of the dynamic tiles using the Bluetooth controller if they rolled the number placed on the tiles and for the second play through it required rolling a pair. We conducted a semi structured interview session when the second play through was finished to receive feedback on their impressions of the differences between the two play through.

Results

The general feedback from the first study was that the participants preferred Hybrid Settlers to the original game because the dynamic tiles added randomness to the game and removed the focus a bit from the usual strategies. When asked about the number of dynamic tiles they responded that no more than one more dynamic tile should be added: "*I will say, no more than one more display. It's also nice that not all the resources can change.*". Furthermore, they added that other parts of the game could potentially be made dynamic as long as there were still tangible elements in the game, such as buildings, development cards and resources. For the center tile (desert and golden chest) they were particularly positive as it changed from being mostly a negative outcome when a seven was rolled to now having the potential of being a positive outcome: "*Even though I did not have a house on the desert piece, I think it was exciting when someone rolled a 7. It will becomes a little more positive to roll 7 instead of the 7's only being negative.*". Additionally, they expressed that risk versus reward of the center tile made them build towards it instead of avoiding it.

For the second study the participants expressed that adding the controller further increased the excitement of the game due to being able to manipulate the resource intake of the opponents by changing the tiles into a resources they did not themselves need. They preferred the single toss game to the pair game because it allowed them to more easily disrupt opponents game by changing tiles they were using. This also showed in the play through in the form of small battles between opponents trying to disrupt their resources. Additionally, being able to change their own tiles to something useful brought more excitement to the game play. Furthermore, we saw an increase of 25% in dynamic tile changes in the single toss game versus the pair toss game.

Discussion

Albeit it is possible to hybridize all tiles on the game board our participants indicated that some of the original game should stay the same, this is also in line with the guidelines in [6]. We believe there are two reasons the participants do not want every tile to be dynamic. *First*, the hybrid tiles are very primitive in graphics, meaning the original style is missing which would result in losing all the detail of the original game board if all tiles were converted to dynamic tiles. *Second*, keeping some of the game board in its original game style ensures the nostalgic feel of the game is preserved. Keeping the nostalgic feeling of the game was the same feedback [1] received after having digitized the game using LEDs showing that as long as some of the game is the same players do not mind digitizing.

Another interesting aspect in Hybrid Settlers that we noticed was how the option to directly disrupt the opponents game increased the excitement. The players would get personal and start small bouts of disrupting each others resource generation and at times more or less focus solely on disrupting a specific players resources or team up with another player to focus on another player. We believe this ability adds more strategy options to the game that are different than what is currently possible using the original game. In general it seems adding dynamic elements to board games that are directly controlled by the players using set rules can add more excitement and strategy options.

Conclusion & Future Work

By designing and fabricating four electrochromic displays in the same hexagonal shape of the original Settlers of Catan tiles we added another dynamic elements that allows for more strategic play and tension. The designs of the displays featured simple iconography of the normal resources designs in the game (wool, grain, brick) to not deviate too much from the original game, in addition we also added a new feature (golden chest) to force some new strategies. Our preliminary studies indicate that players prefer using Hybrid Settlers over the original game as it adds more dimensions and randomness to the game. Also, by allowing the players to manually select which dynamic tiles change resource enable them to get more personal in their strategies as they can directly obstruct an opponents game.

For future work we are interested in exploring how more and more modular elements that can be re-arranged on the fly to create new game board layouts. Furthermore, we also want to investigate in more extensive studies how adding these dynamic elements influence the perception of the game and how they affect the strategies used in a game.

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